

**$^{11}\text{B}(\text{p},\gamma):\text{res}$     1964Al20,1965Se05,1977Ad02**

Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, J. E. Purcell and C. G. Sheu		NP A968, 71 (2017)	1-Jan-2017

- 1964Al20:  $^{11}\text{B}(\text{p},\gamma)$   $E_{\text{p}}=4\text{-}14$  MeV, measured  $\sigma(E,\theta)$ ,  $E_{\gamma}$ .
- 1965Se06:  $^{11}\text{B}(\text{p},\gamma)$   $E_{\text{p}}=0.5\text{-}4.0$  MeV,  $^{12}\text{C}$  deduced levels, nuclear properties.
- 1969Ke02:  $^{11}\text{B}(\text{p},\gamma)$   $E=13\text{-}21$  MeV, measured  $\sigma(E,E_{\gamma},\theta)$ .
- 1972Br26:  $^{11}\text{B}(\text{p},\gamma)$   $E=14\text{-}22$  MeV, measured  $\sigma(E,E_{\gamma},\theta(\gamma))$ .  $^{12}\text{C}$  deduced giant resonance structure, isospin mixing.
- 1972Gi01:  $^{11}\text{B}(\text{pol. p},\gamma)$   $E=6\text{-}14$  MeV, measured analyzing power( $E,\theta$ ).  $^{12}\text{C}$  deduced giant E1 resonance configurations.
- 1972Su08:  $^{11}\text{B}(\text{p},\gamma)$   $E<3$  MeV, measured  $\sigma(E,E_{\gamma},\theta(\gamma-\gamma))$ .  $^{12}\text{C}$  deduced resonance, level-width,  $J$ ,  $\pi$ .
- 1974An19:  $^{11}\text{B}(\text{p},\gamma)$   $E=163$  keV, measured  $\sigma$ .  $^{12}\text{C}$  levels deduced p-width,  $\gamma$ -width, S.
- 1976Ad03:  $^{11}\text{B}(\text{p},\gamma)$ , measured resonance  $\gamma$ .  $^{12}\text{C}$  levels deduced  $\gamma$ -branching.
- 1977Ad02:  $^{11}\text{B}(\text{p},\gamma)$   $E=163$  keV, measured  $\sigma(E_{\gamma})$ .  $^{12}\text{C}$  resonances deduced  $\Gamma$ - $\gamma$ , isospin mixing.
- 1977Fr20:  $^{11}\text{B}(\text{p},\gamma)$   $E=\text{resonance}$ , measured yields.  $^{12}\text{C}$  deduced resonances.
- 1977Sn01:  $^{11}\text{B}(\text{p},\gamma)$   $E=6\text{-}23$  MeV, measured  $\sigma(90^\circ)$  for transitions to the  $0_1^+, 2^+, 0_2^+$ ,  $3^-$  levels In  $^{12}\text{C}$ .
- 1979Ko05:  $^{11}\text{B}(\text{p},\gamma)$   $E=40,60,80$  MeV, measured  $E_{\gamma}$ ,  $I_{\gamma}$ .  $^{12}\text{C}$  deduced evidence for second-harmonic giant resonances.
- 1980Co16:  $^{11}\text{B}(\text{p},\gamma)$   $E=20\text{-}40$  MeV, measured  $\sigma(\theta)$ .
- 1982Co11:  $^{11}\text{B}(\text{p},\gamma)$   $E=5\text{-}14$  MeV, measured  $E_{\gamma}$ , absolute  $\sigma(\theta=90^\circ, E_{\gamma})$ . Deduced total  $\sigma$ .
- 1982Ha12:  $^{11}\text{B}(\text{p},\gamma)$   $E=0.82\text{-}2.83$  MeV, measured  $\sigma(\theta)$  vs  $E$ ,  $\gamma(\theta)$ .  $^{12}\text{C}$  levels deduced  $J$ ,  $\pi$ , transition strengths,  $\Gamma_{\gamma}$ .
- 1982We08:  $^{11}\text{B}(\text{p},\gamma)$   $E=23\text{-}60$  MeV, measured  $\sigma(E)$ .  $^{11}\text{B}(\text{pol. p},\gamma)$   $E=28.7$  MeV, measured  $\sigma(\theta)$ ,  $A(\theta)$ .  $^{12}\text{C}$  deduced possible giant resonances.
- 1982Wr01:  $^{11}\text{B}(\text{p},\gamma)$   $E=2.9\text{-}4.6$  MeV, measured  $E_{\gamma}$ ,  $I_{\gamma}$ ,  $\sigma(\theta)$  vs  $E$ .  $^{12}\text{C}$  transition deduced M1 quenching.
- 1983An09:  $^{11}\text{B}(\text{p},\gamma)$   $E=18\text{-}43$  MeV, measured  $\sigma(\theta)$ .  $^{12}\text{C}$  deduced resonances,  $J$ ,  $\pi$ , interference effects, giant resonance characteristics.
- 1983An16:  $^{11}\text{B}(\text{p},\gamma)$   $E=10\text{-}90$  MeV, measured  $\sigma(\theta)$ . Deduced E1, E2 interference effects.  $^{12}\text{C}$  deduced resonances, configurations.
- 1984Bi10:  $^{11}\text{B}(\text{p},\gamma),(\text{pol. p},\gamma)$   $E=24\text{-}80$  MeV, measured  $\sigma(\theta)$ , analyzing power vs  $\theta$ . Deduced reaction mechanism.
- 1984Ce08,1984Ce03,1985Ce07:  $^{11}\text{B}(\text{p},\gamma)$   $E=163$  keV, measured  $E_{\gamma}$ ,  $I_{\gamma}$ ,  $\Gamma_{\gamma}/\Gamma_a$  branching ratio.
- 1985No01:  $^{11}\text{B}(\text{pol. p},\gamma)$   $E=50$  MeV, measured  $\sigma(\theta)$ ,  $A(\theta)$ . Deduced final state configuration role.
- 1987Ra23:  $^{11}\text{B}(\text{p},\gamma)$   $E=7\text{-}9$  MeV, measured absolute thick target  $\gamma$  yield, relative neutron yield.
- 1988Ha04,1985Ha05:  $^{11}\text{B}(\text{pol. p},\gamma)$   $E=20\text{-}100$  MeV, measured  $E_{\gamma}$ ,  $I_{\gamma}$ ,  $\sigma(\theta)$ , analyzing power vs  $\theta$ .  $^{12}\text{C}$  deduced GDR, parameters, EWSR.
- 1992Ce02:  $^{11}\text{B}(\text{p},\gamma)$   $E=40\text{-}180$  keV, measured capture  $E_{\gamma}$ ,  $I_{\gamma}$ ,  $\gamma(\theta)$ . Deduced astrophysical S-factor.  $^{12}\text{C}$  levels deduced  $\gamma$ -ray to charged particle branching ratio.
- 1992Ho04:  $^{11}\text{B}(\text{p},\gamma)$   $E=98$  MeV, measured  $\sigma(\theta)$ , radiative capture.
- 1993An06:  $^{11}\text{B}(\text{p},\gamma)$   $E=140\text{-}260$  keV, measured thick target yield. Deduced absolute astrophysical S-factor vs  $E$ , electron screening.
- 1993Ho07,1997Tr01:  $^{11}\text{B}(\text{p},\gamma),(\text{P},\text{e}^+\text{e}^-)$   $E=98$  MeV, measured  $\sigma(\theta, E_{\gamma})$ ,  $\sigma(\theta)$ , pair production energy spectra, invariant mass distribution. Deduced reaction mechanism.
- 1996Br20:  $^{11}\text{B}(\text{p},\gamma)$   $E=98,176$  MeV, measured  $\sigma(\theta)$ . Deduced reaction mechanism.
- 2000Ke10:  $^{11}\text{B}(\text{pol. p},\gamma)$   $E<100$  keV, measured  $E_{\gamma}$ ,  $I_{\gamma}$ ,  $\sigma$ ,  $A_{\gamma}(\theta=90^\circ)$ . Deduced astrophysical S-factor, influence of low-lying resonances.
- 2004Ch06:  $^{11}\text{B}(\text{p},\gamma)$   $E=7.2, 17\text{-}24$  MeV, measured  $E_{\gamma}$ ,  $I_{\gamma}$ ,  $\sigma$ . Deduced GDR contribution.  $^{12}\text{C}$  deduced GDR energy, width.
- 2008Ch13:  $^{11}\text{B}(\text{p},\gamma)$   $E=7\text{-}24.5$  MeV, measured  $E_{\gamma}$ ,  $I_{\gamma}$ , capture cross sections.  $^{12}\text{C}$  deduced resonances.
- 2016He05: XUNDL dataset compiled by TUNL, 2016.
- Beams of 160 to 310 keV protons, from the Lanzhou Institute of Modern Physics 320-kV platform, impinged on a  $6.3 \mu\text{g/cm}^2$  natural boron target (80%  $^{11}\text{B}$ ). The capture  $\gamma$ -rays were detected in a  $4\times 4$  HPGe clover detector (200% efficiency relative to a 3 inch $\times$ 3 inch NaI detector). Events were analyzed in singles mode to minimize complications from cascade summing. The detector efficiencies were determined using standard calibration sources and  $\gamma$  rays populated in the  $^{14}\text{N}(\text{p},\gamma)$  reaction. The present results determined  $E_{\text{c.m.}}(\text{res})=150.0$  keV 5 and  $\Gamma_{\text{c.m.}}=5.0$  keV 8 for  $^{12}\text{C}^*(16.1 \text{ MeV})$ . In addition, in the region of  $E_{\text{c.m.}}=170$  to 240 keV the authors find a  $\approx$ 15-50% enhanced cross section when compared with previous results.
- 2016La27: A beam of  $E\approx 163$  keV protons, from the Aarhus Van de Graaff accelerator, impinged on natural boron targets with thicknesses near  $10\text{-}15 \mu\text{g/cm}^2$  that were placed with a steep angle with respect the incident beam. A set of two 5 cm $\times$ 5 cm double-sided Si strip detectors were positioned 2.5 cm from the target on the horizontal axis and covered  $\theta_1=60^\circ$  to  $150^\circ$  and

**$^{11}\text{B}(\text{p},\gamma):\text{res}$     1964Al20,1965Se05,1977Ad02 (continued)**

$\theta_2 = -35^\circ$  to  $-120^\circ$ ; particles emitted roughly perpendicular to the incident beam were detected.

The events with three  $\alpha$  particles detected in the final state are analyzed to obtain the  $^{12}\text{C}$  excitation energy. While the  $3\alpha$  reconstructed energy spectrum is expected to be dominated by the  $\alpha_0$  (5%) and  $\alpha_1$  (90%) decays to  $^8\text{Be}$ , additional peaks appear in the spectrum; these peaks correspond to the sequential process of  $\gamma$  decay to lower  $^{12}\text{C}$  states followed by  $\alpha$  emission. Peaks corresponding to  $\alpha$  decay from  $^{12}\text{C}^*(9641,10847,12710)$  are observed along with unresolved strength to other states with  $E_x = 9.8$  to 10.25 MeV and  $E_x = 11.5$  to 13.0 MeV. The branching ratios for  $\gamma$  decay to  $\alpha$  particle unbound levels are first deduced, then the partial widths are deduced using  $\Gamma = 5.3$  keV 2.

 **$^{12}\text{C}$  Levels**

E(level)	$J^\pi$	$\Gamma$	Comments
0			
4440			
7654			
9641			
10847			
12710			
15110			
16106.9	6	2+	$T=1$ ; $\Gamma_{\gamma 0}/\Gamma_{\gamma 1}=0.046$ 7; $\Gamma_{\gamma 1}/\Gamma_\gamma=2.42 \times 10^{-3}$ 29 $\Gamma_{\gamma 0}=0.59$ eV 11; $\Gamma_p=21.5$ eV 33; $\Gamma_{\gamma 1}=12.8$ eV 18 ( <a href="#">1977Ad02</a> ) E(level): Deduced using $E_{\text{res}}=150.0$ keV 5 and $S_p=15956.85$ keV 42; see ( <a href="#">2016He05</a> ). For adopted E: from $E_{\text{res}}(\text{c.m.})=149.1$ keV 7. This is the weighted average (Limitation of Statistical Weights Method) of the values 16106.9 keV 6 ( <a href="#">2016He05</a> ) from ( $p,\gamma$ ) and 16105.2 keV 4 ( <a href="#">1987Be17</a> ) and 16106.7 keV 4 ( <a href="#">1979Da03</a> ) from ( $p,\alpha$ ). The adopted value is $E_x=16106.0$ keV 8.
16576	2-	300 keV	$T=1$ ; $\Gamma_{\gamma 0}=48 \times 10^{-3}$ eV 8; $\Gamma_{\alpha 0}<0.27$ keV; $\Gamma_p=150$ keV $\Gamma_{\gamma 1}=8.0$ eV; $\Gamma_{\alpha 1}=150$ keV ( <a href="#">1965Se06</a> )
17230	1-	1150 keV	$T=1$ ; $\Gamma_{\gamma 0}=44$ eV; $\Gamma_{\alpha 0}=10$ keV; $\Gamma_p=1$ MeV $\Gamma_{\gamma 1}=5.$ eV; $\Gamma_{\alpha 1}=140$ keV ( <a href="#">1965Se06</a> )
$17.76 \times 10^3$	0+	96 keV 5	$T=1$ ; $\Gamma_{\alpha 0}=4.6$ keV; $\Gamma_p=76$ keV $\Gamma_{\alpha 1}=111.4$ keV ( <a href="#">1965Se06</a> )
$18.13 \times 10^3$	(1+)	0.60 MeV 10	$T=0$
$18.38 \times 10^3$	3-	$\approx 400$ keV	$T=1$ ; $\Gamma_{\gamma 0} \approx 2 \times 10^{-3}$ eV; $\Gamma_{\alpha 0}=65$ keV; $\Gamma_p=68$ keV $\Gamma_{\gamma 1}=3.2$ eV; $\Gamma_{\alpha 1}=177$ keV ( <a href="#">1965Se06</a> )
$18.39 \times 10^3$	0-	43 keV	$\Gamma_{\gamma 0}<0.5$ eV; $\Gamma_{\alpha 0}<1$ keV; $\Gamma_p=33$ keV $\Gamma_{\gamma 1}<0.5$ eV; $\Gamma_{\alpha 1}<5$ keV ( <a href="#">1965Se06</a> )
$18.81 \times 10^3$	2+	100 keV	$T=1$ ; $\Gamma_{\gamma 0}=0.4$ eV; $\Gamma_{\alpha 0}<0.2$ keV; $\Gamma_p=97$ keV $\Gamma_{\gamma 1}=2.0$ eV; $\Gamma_{\alpha 1}<1.5$ keV ( <a href="#">1965Se06</a> )
$19.2 \times 10^3$	(1-)	1100 keV	$T=1$ ; $\Gamma_{\gamma 0}=25$ eV; $\Gamma_{\alpha 0}=50$ keV; $\Gamma_p=300$ keV $\Gamma_{\gamma 1}=10.$ eV; $\Gamma_{\alpha 1}=200$ keV ( <a href="#">1965Se06</a> )
$19.39 \times 10^3$	(2+)	1100 keV	$T=0$ ; $\Gamma_{\gamma 0}<3$ eV; $\Gamma_{\alpha 0}=20$ keV; $\Gamma_p=450$ keV $\Gamma_{\gamma 1}=3.$ eV; $\Gamma_{\alpha 1}=450$ keV ( <a href="#">1965Se06</a> ) E(level), $J^\pi$ : From ( <a href="#">1955Ba22,1963Sy01</a> ). E(level): From ( <a href="#">1955Ba22,1963Sy01</a> ).
$20.47 \times 10^3$		180 keV	E(level): From ( <a href="#">1955Ba22,1963Sy01</a> ).
$20.64 \times 10^3$	(3-)	275 keV	$T=1$ E(level), $J^\pi$ : From ( <a href="#">1955Ba22,1963Sy01</a> ). E(level): From ( <a href="#">1964Al20</a> ).
$21.5 \times 10^3$			E(level): From ( <a href="#">1964Al20</a> ).
$22.1 \times 10^3$		500 keV	E(level): From ( <a href="#">1964Al20</a> ).
$22.6 \times 10^3$	(1-)	3200 keV	$T=1$ ; $\Gamma_{\gamma 0}>2500$ keV E(level), $J^\pi$ : From ( <a href="#">1964Al20</a> ).
$23.6 \times 10^3$			E(level): From ( <a href="#">1964Al20</a> ).
$24.41 \times 10^3$		1.3 MeV 3	E(level): From ( <a href="#">2008Ch13</a> ). $(2J+1)\Gamma_{p0}\Gamma_g/\Gamma=20.8$ 28.
$25.4 \times 10^3$		$\approx 6500$ keV	E(level): From ( <a href="#">1964Al20</a> ).
$26.72 \times 10^3$	(1-)	$\approx 700$ keV	E(level), $J^\pi$ : From ( <a href="#">1964Al20,1967Fe04</a> ). E(level): From ( <a href="#">1967Fe04</a> ).
$27.4 \times 10^3$			

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$^{11}\text{B}(\text{p},\gamma):\text{res}$  **1964Al20,1965Se05,1977Ad02 (continued)** $^{12}\text{C}$  Levels (continued)

E(level)	$\Gamma$				Comments
$27.94 \times 10^3$		E(level), $J^\pi$ : From (1964Al20, 1967Fe04).			
$28.6 \times 10^3$	$\approx 2500$ keV	E(level): From (1967Fe04).			
$28.81 \times 10^3$	2.0 MeV	E(level): From (2008Ch13).			
$29.0 \times 10^3$		E(level): From (1967Fe04).			
$29.5 \times 10^3$		E(level): From (1969Ke02). $\Gamma$ : Broad.			

 $\gamma(^{12}\text{C})$ 

$E_\gamma$	$I_\gamma$	$E_i(\text{level})$	$J_i^\pi$	$E_f$	Mult.		Comments
3020	100	$18.13 \times 10^3$	(1 <sup>+</sup> )	15110			
3396	1.46 25	16106.9	2 <sup>+</sup>	12710			
4438	100	4440		0	E2		
5050	100	$17.76 \times 10^3$	0 <sup>+</sup>	12710			
5259		16106.9	2 <sup>+</sup>	10847	E1		
6465	2.4 4	16106.9	2 <sup>+</sup>	9641			
8739	100	$18.38 \times 10^3$	3 <sup>-</sup>	9641			
$9.31 \times 10^3$		$24.41 \times 10^3$		15110			
11662	100	16106.9	2 <sup>+</sup>	4440	M1	$I_\gamma$ : From (1965Se06).	
12129	100	16576	2 <sup>-</sup>	4440		$I_\gamma$ : From (1965Se06).	
12782	11	17230	1 <sup>-</sup>	4440			
$13.7 \times 10^3$		$28.81 \times 10^3$		15110			
13942	56	$18.38 \times 10^3$	3 <sup>-</sup>	4440			
14372	100	$18.81 \times 10^3$	2 <sup>+</sup>	4440		$I_\gamma$ : From (1965Se06).	
$14.76 \times 10^3$	40	$19.2 \times 10^3$	(1 <sup>-</sup> )	4440			
14950	100	$19.39 \times 10^3$	(2 <sup>+</sup> )	4440		$I_\gamma$ : From (1965Se06).	
16094	4.6 7	16106.9	2 <sup>+</sup>	0	E2		
16564	0.6 1	16576	2 <sup>-</sup>	0			
17217	100	17230	1 <sup>-</sup>	0		$I_\gamma$ : From (1965Se06).	
$17.7 \times 10^3$		$22.1 \times 10^3$		4440			
18380	$3.5 \times 10^{-4}$	$18.38 \times 10^3$	3 <sup>-</sup>	0			
18810	<20	$18.81 \times 10^3$	2 <sup>+</sup>	0			
$19.07 \times 10^3$		$26.72 \times 10^3$	(1 <sup>-</sup> )	7654			
$19.2 \times 10^3$	100	$19.2 \times 10^3$	(1 <sup>-</sup> )	0		$I_\gamma$ : From (1965Se06).	
$19.2 \times 10^3$		$23.6 \times 10^3$		4440			
$20.47 \times 10^3$		$20.47 \times 10^3$		0			
$20.64 \times 10^3$		$20.64 \times 10^3$	(3 <sup>-</sup> )	0			
$21.0 \times 10^3$		$25.4 \times 10^3$		4440			
$21.5 \times 10^3$		$21.5 \times 10^3$		0			
$22.1 \times 10^3$		$22.1 \times 10^3$		0			
$22.28 \times 10^3$		$26.72 \times 10^3$	(1 <sup>-</sup> )	4440			
$22.6 \times 10^3$		$22.6 \times 10^3$	(1 <sup>-</sup> )	0			
$23.5 \times 10^3$		$27.94 \times 10^3$		4440			
$23.6 \times 10^3$		$23.6 \times 10^3$		0			
$24.1 \times 10^3$		$28.6 \times 10^3$		4440			
$25.4 \times 10^3$		$25.4 \times 10^3$		0			
$27.4 \times 10^3$		$27.4 \times 10^3$		0			
$27.94 \times 10^3$		$27.94 \times 10^3$		0			

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 $^{11}\text{B}(\text{p},\gamma):\text{res}$     1964Al20,1965Se05,1977Ad02 (continued) $\gamma(^{12}\text{C})$  (continued)

$E_\gamma$	$E_i(\text{level})$	$E_f$
$29.0 \times 10^3$	$29.0 \times 10^3$	0
$29.5 \times 10^3$	$29.5 \times 10^3$	0

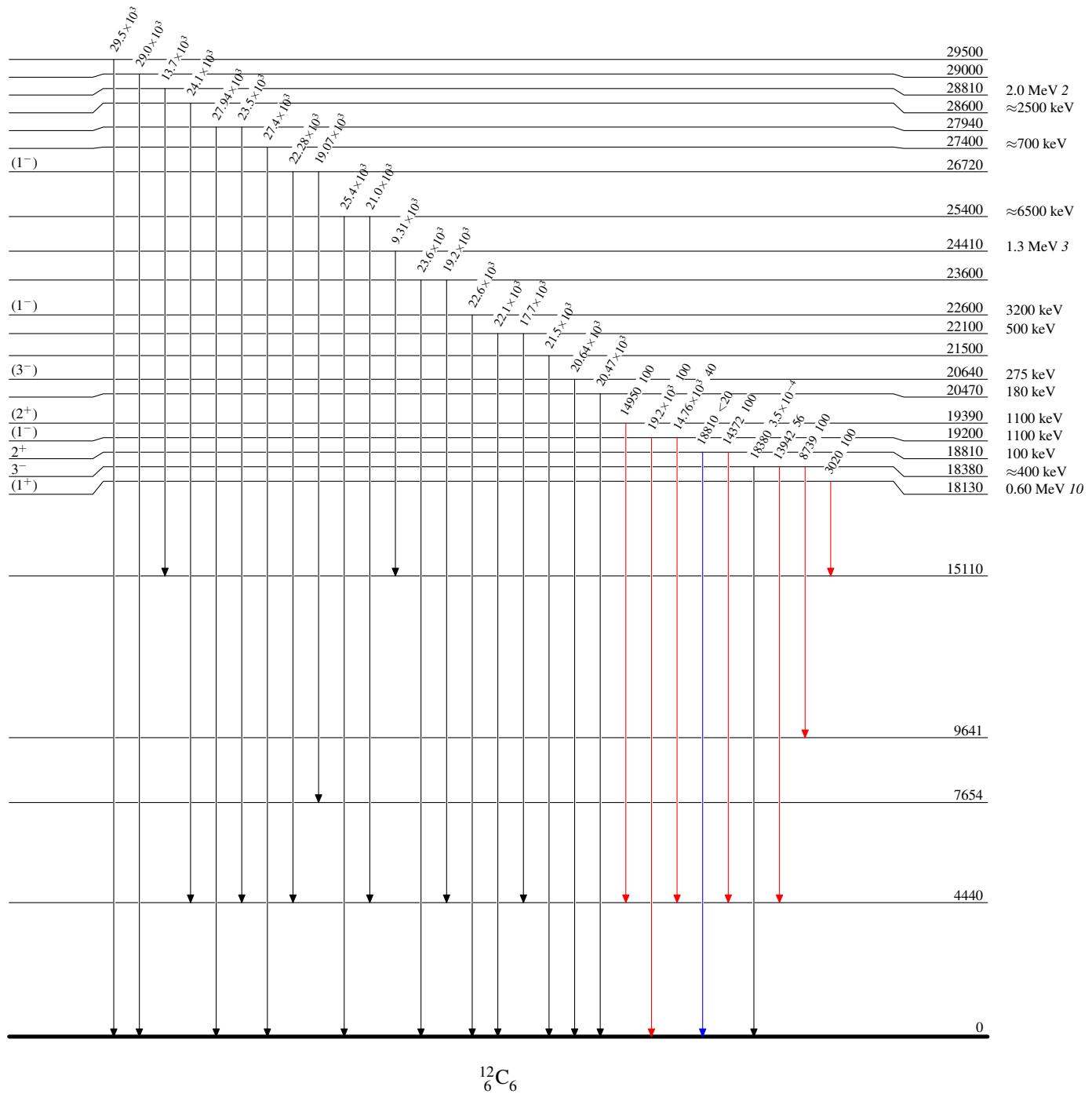
$^{11}\text{B}(\text{p},\gamma):\text{res}$     1964Al20,1965Se05,1977Ad02

## Legend

## Level Scheme

Intensities: Relative  $I_\gamma$ 

- $I_\gamma < 2\% \times I_{\gamma}^{\max}$
- $I_\gamma < 10\% \times I_{\gamma}^{\max}$
- $I_\gamma > 10\% \times I_{\gamma}^{\max}$

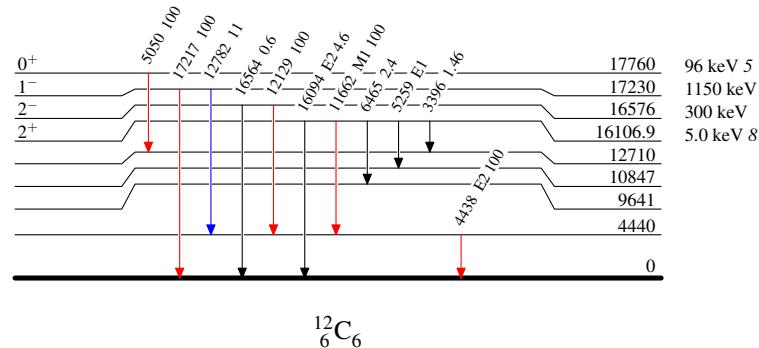


$^{11}\text{B}(\text{p},\gamma):\text{res}$     1964Al20,1965Se05,1977Ad02Level Scheme (continued)

## Legend

Intensities: Relative  $I_\gamma$ 

- $\rightarrow$   $I_\gamma < 2\% \times I_{\gamma}^{\max}$
- $\rightarrow$   $I_\gamma < 10\% \times I_{\gamma}^{\max}$
- $\rightarrow$   $I_\gamma > 10\% \times I_{\gamma}^{\max}$

 $^{12}_6\text{C}_6$